Watching Aerosols from Space

Chylek was thinking about how aerosols affected climate long before it was a hot topic. Thirty-four years ago, while a researcher at the National Center for Atmospheric Research, Chylek published a paper entitled "Aerosols and Climate" in the prestigious journal Science. In that 1974 paper, he pointed out the need for accurate aerosol measurements and ended on a note of hope, speculating that "someday their effect may be measured directly when changes in the albedo of the earth-atmosphere system are remotely monitored by satellites." That day has come and Chylek, now remote-sensing team leader in Los Alamos' International, Space, and Response Division, is now in the satellite business.

Chylek's work builds on Los Alamos' history of using satellites to detect the illicit production of weapons of mass destruction. One of those satellites, the Multispectral Thermal Imager (MTI), has circled the planet since March 2000, collecting images of the Earth with instruments that see changes in light and heat that the human eye cannot. While looking for the telltale gases, dusts, and heat produced by chemical or nuclear activity, the MTI has produced mountains of environmental data. Chylek took on the task of figuring out what nondefense questions might also be answered with MTI's data, and there was the answer to his hopes from 1974—global pictures of aerosols.

But the MTI didn't just hand over ready-made answers. It provided measurements of radiance (light intensity) that Chylek and his team had to translate into accurate information about aerosol optical depth. After extensive calibrations with ground observations, Chylek hit upon a method that turned out to be highly accurate. For more global atmospheric data, Chylek turned to NASA's satellite-mounted MODIS instrument, which images the entire Earth every 1 to 2 days. While NASA had its own way to calculate aerosol optical depth, Chylek's method reduced the error by a factor of 2 to 3. This led to surprising observations of aerosol behavior over the Indian Ocean, a long way from the Arctic but involving the same culprit: black carbon.

Satellite observations near India were as expected for lower-altitude water clouds but surprising for higher-altitude ice clouds. Increased pollution during the winter created many smaller cloud droplets (purple) in water clouds. But human-generated soot led to fewer but larger droplets in ice clouds, allowing more solar radiation through.

During the winter, pollution increases dramatically over the Indian subcontinent, affecting cloud formation. As expected, Chylek found that more aerosols produced more and smaller cloud droplets, reflecting more sunlight back into space. But at altitudes where icy cirrus clouds form, the result was, surprisingly, the opposite—fewer but larger ice crystals letting more solar radiation through to the surface. This puzzling reaction was caused by the water-attracting properties of black carbon, and between the recent growth of industry and the longstanding practice of burning wood and coal as household fuels, India produces a lot of soot. In the dance between aerosols and water vapor, water snubs the other aerosols, and clings to the soot, which has the additional power to initiate freezing at just a few degrees below zero. In contrast, water condensed around sulfate particles can remain liquid up to –40°C. So water freezes quickly onto soot, depletes atmospheric moisture, and leaves many aerosols without a condensation partner. Climate models were not including this reaction.

Chylek's and Dubey's work complement each other well. Dubey measures aerosols over a city here and a region there while flying at different altitudes, which leads to highly detailed results, but it would require years to combine those details into a global picture. Chylek's satellite observations lack the detail, seeing only optical averages of a whole column of aerosols from surface to satellite, but allow analysis of the entire planet in just days. Together, their work produces the stuff that better climate models are made of.